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CHEMISTRY
HIGHER LEVEL
PAPER 2

Tuesday 3 November 2009 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

0114

SECTION A

*Answer **all** the questions in the spaces provided.*

1. The data below is from an experiment used to determine the percentage of iron present in a sample of iron ore. This sample was dissolved in acid and all of the iron was converted to Fe^{2+}. The resulting solution was titrated with a standard solution of potassium manganate(VII), $KMnO_4$. This procedure was carried out three times. In acidic solution, MnO_4^- reacts with Fe^{2+} ions to form Mn^{2+} and Fe^{3+} and the end point is indicated by a slight pink colour.

Titre	**1**	**2**	**3**
Initial burette reading / cm^3	1.00	23.60	10.00
Final burette reading / cm^3	24.60	46.10	32.50

Mass of iron ore / g	3.682×10^{-1}
Concentration of $KMnO_4$ solution / mol dm^{-3}	2.152×10^{-2}

(a) Deduce the balanced redox equation for this reaction in **acidic** solution. *[2]*

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(b) Identify the reducing agent in the reaction. *[1]*

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(c) Calculate the amount, in moles, of MnO_4^- used in the titration. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(d) Calculate the amount, in moles, of Fe present in the 3.682×10^{-1} g sample of iron ore. *[2]*

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(e) Determine the percentage by mass of Fe present in the 3.682×10^{-1} g sample of iron ore. *[2]*

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2. SF_2, SF_4 and SF_6 have different shapes. Draw their Lewis structures and use the VSEPR theory to predict the name of the shape of each molecule. *[6]*

	SF_2	SF_4	SF_6
Lewis structure			
Name of shape	. . . . .	. . . . .	. . . . .

3. (a) Describe the emission spectrum of hydrogen. Outline how this spectrum is related to the energy levels in the hydrogen atom. *[3]*

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(b) Transition elements form complexes such as $[Fe(CN)_6]^{4-}$ and $[FeCl_4]^-$. Deduce the oxidation number of iron in each of these complex ions. *[2]*

$[Fe(CN)_6]^{4-}$ . . . . . .

$[FeCl_4]^-$ . . . . . .

4. (a) Outline **two** differences between an electrolytic cell and a voltaic cell. *[2]*

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(b) Consider the following half-cell reactions and their standard electrode potentials.

$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \quad E^{\ominus} = -0.26\,V$$
$$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s) \quad E^{\ominus} = -1.66\,V$$

(i) Deduce a balanced equation for the overall reaction which will occur spontaneously when these two half-cells are connected. *[2]*

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(ii) Determine the cell potential when the two half-cells are connected. *[1]*

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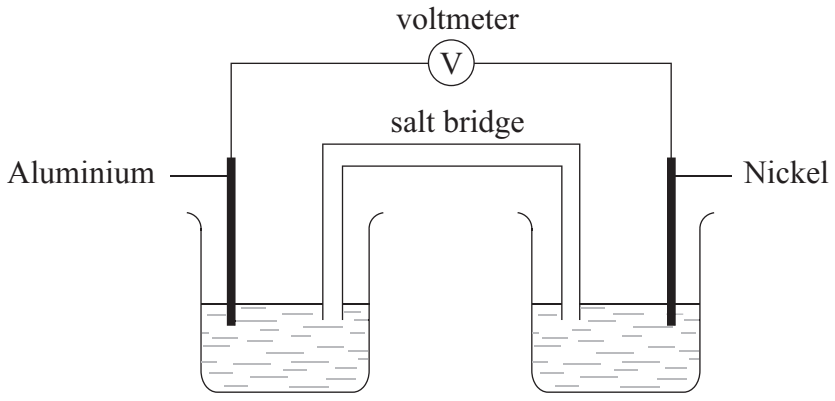
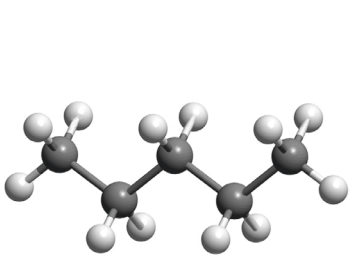
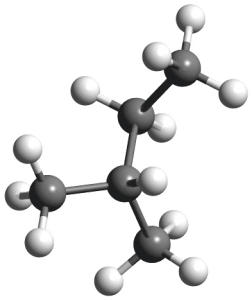
(iii) On the cell diagram below, label the negative electrode (anode), the positive electrode (cathode) and the directions of the movement of electrons and ion flow. *[4]*



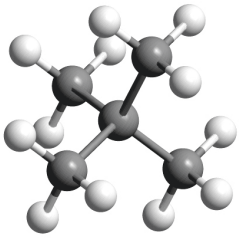
5. (a) The boiling points of the isomers of pentane, C_5H_{12}, shown are 10, 28 and 36 °C, but not necessarily in that order.



A



B



C

(i) Identify the boiling points for each of the isomers **A**, **B** and **C** and state a reason for your answer. *[3]*

Isomer	**A**	**B**	**C**
Boiling point			

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(ii) State the IUPAC names of isomers **B** and **C**. *[2]*

B: . . . . . .

C: . . . . . .

(b) Both C_5H_{12} and $C_5H_{11}OH$ can be used as fuels. Predict which compound would release a greater amount of heat per gram when it undergoes complete combustion. Suggest **two** reasons to support your prediction. *[3]*

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(Question 5 continued)

(c) In many cities around the world, public transport vehicles use diesel, a liquid hydrocarbon fuel, which often contains sulfur impurities and undergoes incomplete combustion. All public transport vehicles in New Delhi, India, have been converted to use compressed natural gas (CNG) as fuel. Suggest **two** ways in which this improves air quality, giving a reason for your answer. *[3]*

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SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

6. (a) Consider the following reaction studied at 263 K.

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$$

It was found that the forward reaction is first order with respect to Cl_2 and second order with respect to NO. The reverse reaction is second order with respect to NOCl.

(i) State the rate expression for the forward reaction. *[1]*

(ii) Predict the effect on the rate of the forward reaction and on the rate constant if the concentration of NO is halved. *[2]*

(iii) 1.0 mol of Cl_2 and 1.0 mol of NO are mixed in a closed container at constant temperature. Sketch a graph to show how the concentration of NO and NOCl change with time until after equilibrium has been reached. Identify the point on the graph where equilibrium is established. *[4]*

(b) Consider the following reaction.

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

Possible reaction mechanisms are:

Above 775 K:	$NO_2 + CO \rightarrow NO + CO_2$	*slow*
Below 775 K:	$2NO_2 \rightarrow NO + NO_3$	*slow*
	$NO_3 + CO \rightarrow NO_2 + CO_2$	*fast*

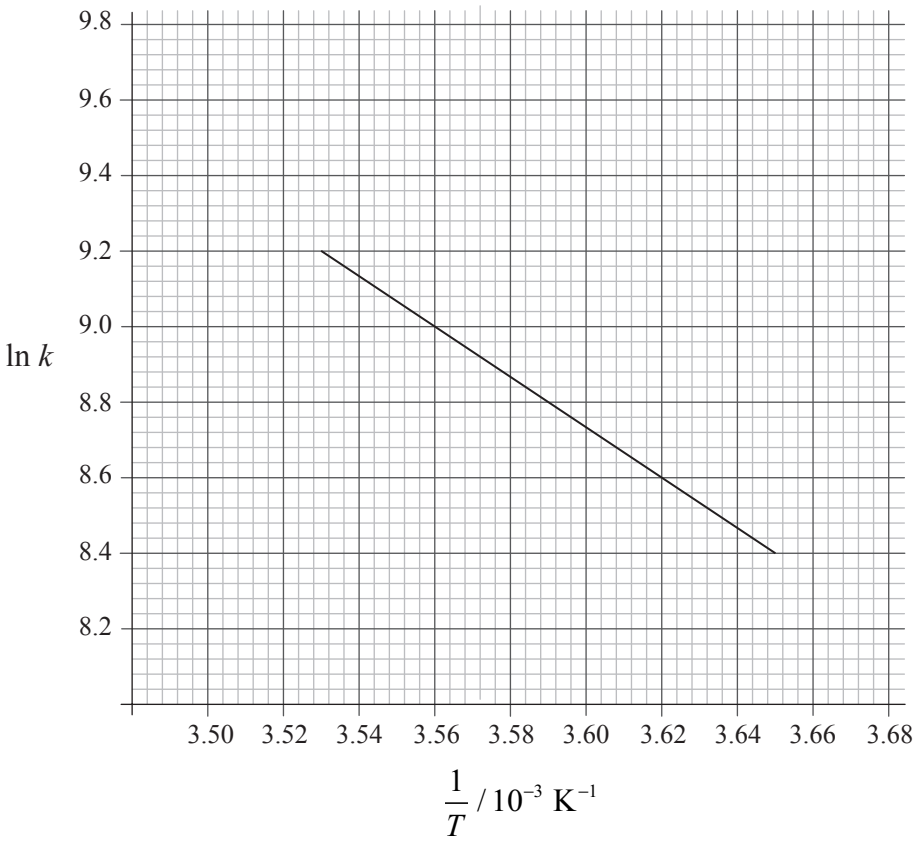
Based on the mechanisms, deduce the rate expressions above and below 775 K. *[2]*

(c) State **two** situations when the rate of a chemical reaction is equal to the rate constant. *[2]*

(This question continues on the following page)

(Question 6 continued)

(d) Consider the following graph of ln *k* against $\frac{1}{T}$ for the first order decomposition of N_2O_4 into NO_2. Determine the activation energy in kJ mol^{-1} for this reaction. *[2]*



(e) Consider the following equilibrium reaction.

$$Cl_2(g) + SO_2(g) \rightleftharpoons SO_2Cl_2(g) \qquad \Delta H^{\ominus} = -84.5 \text{ kJ}$$

In a 1.00 dm^3 closed container, at 375 °C, 8.60×10^{-3} mol of SO_2 and 8.60×10^{-3} mol of Cl_2 were introduced. At equilibrium, 7.65×10^{-4} mol of SO_2Cl_2 was formed.

(i) Deduce the equilibrium constant expression, K_c, for the reaction. *[1]*

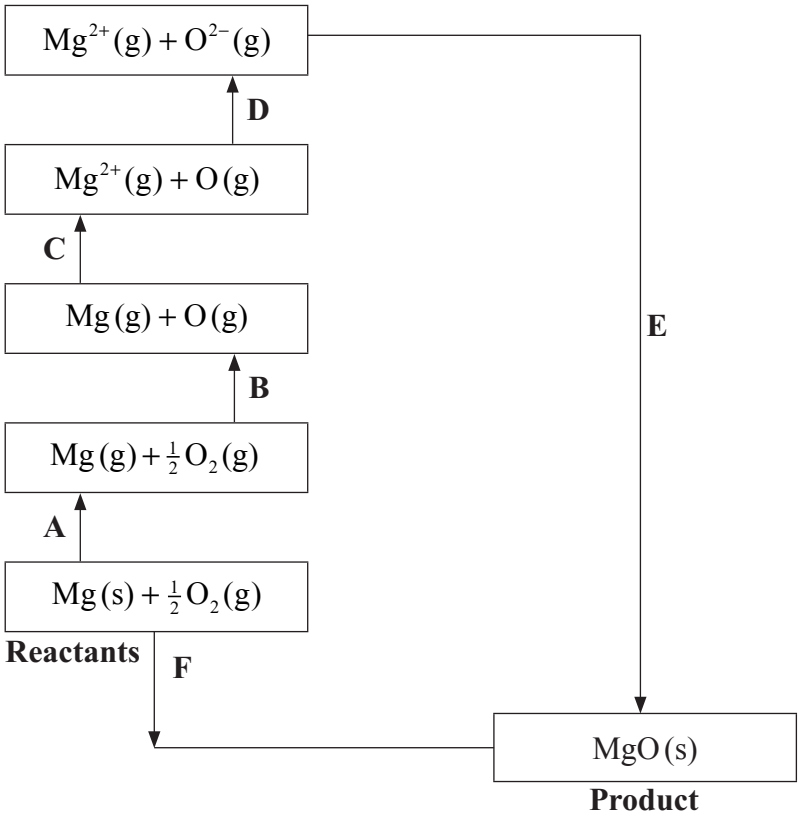
(ii) Determine the value of the equilibrium constant, K_c. *[3]*

(iii) If the temperature of the reaction is changed to 300 °C, predict, stating a reason in each case, whether the equilibrium concentration of SO_2Cl_2 and the value of K_c will increase or decrease. *[3]*

(iv) If the volume of the container is changed to 1.50 dm^3, predict, stating a reason in each case, how this will affect the equilibrium concentration of SO_2Cl_2 and the value of K_c. *[3]*

(v) Suggest, stating a reason, how the addition of a catalyst at constant pressure and temperature will affect the equilibrium concentration of SO_2Cl_2. *[2]*

7. (a) The Born-Haber cycle for MgO under standard conditions is shown below.



The values are shown in the table below.

Process	Enthalpy change / kJ mol^{-1}
A	+150
B	+248
C	+736 + (+1450)
D	–142 + (+844)
E	
F	–602

(i) Identify the processes represented by **A**, **B** and **D** in the cycle. *[3]*

(ii) Define the enthalpy change, **F**. *[2]*

(iii) Determine the value of the enthalpy change, **E**. *[2]*

(iv) Define the enthalpy change **C** for the first value. Explain why the second value is significantly larger than the first. *[4]*

(This question continues on the following page)

(Question 7 continued)

(v) The inter-ionic distance between the ions in NaF is very similar to that between the ions in MgO. Suggest with a reason, which compound has the higher lattice enthalpy value. *[2]*

(b) (i) The standard enthalpy change of three combustion reactions is given below in kJ.

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l) \qquad \Delta H^{\ominus} = -3120$$
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H^{\ominus} = -572$$
$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) \qquad \Delta H^{\ominus} = -1411$$

Based on the above information, calculate the standard change in enthalpy, $\Delta H^{\ominus}$, for the following reaction.

$$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$$ *[4]*

(ii) Predict, stating a reason, whether the sign of $\Delta S^{\ominus}$ for the above reaction would be positive or negative. *[2]*

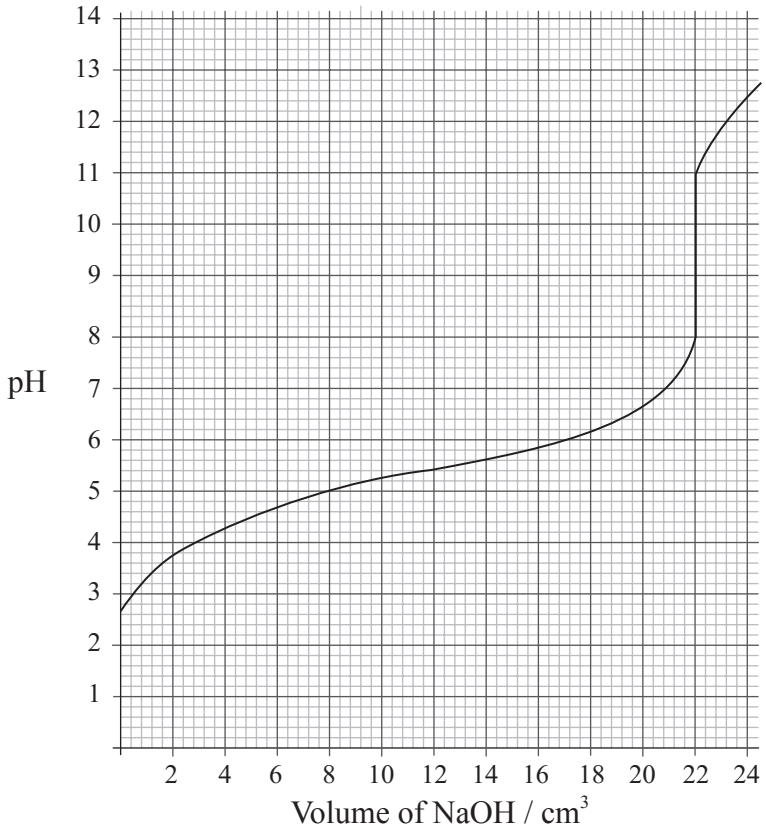
(iii) Discuss why the above reaction is non-spontaneous at low temperature but becomes spontaneous at high temperatures. *[2]*

(iv) Using bond enthalpy values, calculate $\Delta H^{\ominus}$ for the following reaction.

$$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$$ *[3]*

(v) Suggest with a reason, why the values obtained in parts (b) (i) and (b) (iv) are different. *[1]*

8. (a) A 25.0 cm^3 solution of a weak monoprotic acid, HA (aq), is titrated with 0.155 $mol\,dm^{-3}$ sodium hydroxide, NaOH (aq), and the following graph is obtained.



(i) Determine the pH at the equivalence point. *[1]*

(ii) Explain, using an equation, why the equivalence point is not at pH = 7. *[3]*

(iii) Calculate the concentration of the weak acid before the addition of any NaOH (aq). *[2]*

(iv) Estimate, using data from the graph, the dissociation constant, K_a, of the weak acid, HA, showing your working. *[3]*

(v) Suggest an appropriate indicator for this titration. *[1]*

(b) Describe qualitatively the action of an acid-base indicator. *[3]*

(c) (i) Explain what is meant by the term *buffer solution*. *[2]*

(ii) Calculate the pH of a solution prepared by mixing 50.0 cm^3 of 0.200 $mol\,dm^{-3}$ CH_3COOH (aq) and 50.0 cm^3 of 0.100 $mol\,dm^{-3}$ NaOH (aq), showing your working. *[3]*

(This question continues on the following page)

(Question 8 continued)

(d) State whether $AlCl_3$ is acidic, basic or neutral in an aqueous solution. Write an equation to support your answer. *[2]*

(e) 0.100 mol of ammonia, NH_3, was dissolved in water to make 1.00 dm^3 of solution. This solution has a hydroxide ion concentration of $1.28\times10^{-3}\,mol\,dm^{-3}$.

(i) Determine the pH of the solution. *[2]*

(ii) Calculate the base dissociation constant, K_b, for ammonia. *[3]*

9. (a) The compound C_4H_7Cl can exhibit stereoisomerism.

(i) Draw the structural formulas of the **two** geometrical isomers of 1-chloro-but-2-ene. *[2]*

(ii) Explain why 1-chloro-but-2-ene shows geometrical isomerism. *[1]*

(iii) Draw the structural formula of **one** isomer of C_4H_7Cl that shows optical isomerism and identify the chiral carbon atom with an asterisk (*). *[2]*

(b) The compound but-2-ene-1,4-dioic acid forms two geometrical isomers which have different physical and chemical properties.

(i) Explain the difference in the melting points of the two isomers. *[3]*

(ii) Outline how the two isomers behave differently when gently heated. *[1]*

(c) The reaction between bromoethane, CH_3CH_2Br, and potassium cyanide is an example of a nucleophilic substitution reaction.

(i) State whether this reaction is S_N1 or S_N2. *[1]*

(ii) Explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs. *[4]*

(iii) The organic product obtained in part (c) (ii) can be reduced to form an amine. State an equation for the reaction, naming the catalyst involved. *[2]*

(d) Bromoethane reacts with potassium hydroxide to undergo mainly a substitution reaction or an elimination reaction depending on the reaction conditions used.

(i) State an equation and the reaction conditions used to control the products formed in each case. *[4]*

(ii) Explain the mechanism of the elimination reaction using curly arrows to represent the movement of electron pairs. *[4]*

(iii) Under certain conditions, the major product obtained in the elimination reaction can undergo polymerization. Identify the type of polymerization this major product undergoes. *[1]*